EVALUATING THE EFFECTS OF PROHIBITING LEFT TURNS AND THE RESULTING U-TURN MOVEMENT

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EVALUATING THE EFFECTS OF PROHIBITING LEFT TURNS AND THE RESULTING U-TURN MOVEMENT

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ABSTRACT

EVALUATING THE EFFECTS OF PROHIBITING LEFT TURNS AND THE RESULTING U-TURN MOVEMENT

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The Ohio Department of Transportation (ODOT) Access Management Manual (2002) covers most forms of access management. However, it does not effectively address the effect of prohibiting left turns from a facility to the mainline. In some cases, it may be beneficial, operationally and/or in terms of safety, to restrict the direct left turn by use of right-in/right-out channelization and provide an alternative movement. However, the lack of comprehensive research performed on this topic has caused a deficiency in standards related to left turn treatments at driveways.

Some traffic engineering experts suggest that the combination of a right turn and U-turn as opposed to a direct left-turn from a driveway may significantly improve safety, depending on traffic and geometric conditions. Still, there is a lack of field data to prove these theories. Many alternative designs exist to

accommodate the diverted left-turn traffic from a business, residential, or commercial development that can reduce the risk of adversely affecting nearby intersections. Through a survey of state agencies, a summary of best-practices was developed. The results of the survey, in addition to the reviewed literature, provided guidance in choosing the alternatives to be evaluated for use in Ohio. The alternatives were evaluated operationally as well as for safety. The operational analysis did not provide any definite trends for use of a certain alternative to the direct left turn. However, the safety investigation proved that alternatives to direct left turns reduce conflict points and, in turn, may reduce crashes. Therefore, decisions must be made on a case-by-case basis.

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CHAPTER I

INTRODUCTION

1.1 Problem Statement

"Left turn" treatments at driveways and street intersections are an important element of access management. However, the Ohio Department of Transportation (ODOT) Access Management Manual (2002) does not address the effect of prohibiting left turns from a roadside facility using right-in, right-out restrictions on traffic movement. The lack of comprehensive research performed on this topic has caused a deficiency in standards related to left turn treatments at driveways.

It has been suggested by traffic engineering experts that the combination of a right turn and U-turn as opposed to a direct left-turn may significantly reduce traffic conflict points and improve safety, depending on traffic and geometric conditions. However, there is a lack of field data to prove these theories. Also, motorists often do not favor the forced right turn then U-turn due to the perception of a longer travel time compared to the direct left turn or they may feel that a U-turn is an illegal movement even when not restricted.

Studies have suggested different operational and safety implications of specific left-turn treatments on the roadside facility and on the through-traffic lanes. The restriction of the left turn may have a negative effect on the nearest intersection since the drivers are forced to make a U-turn at the intersection if a mid-block U-turn is not provided before or after the intersection. This requires a longer left-turn phase at the signalized intersections, which may further delay through-moving vehicles. This may also require a change in the geometry of the road to accommodate U-turns for larger vehicles, such as trucks.

Many alternative designs exist to accommodate the diverted left-turn traffic from a business, residential, or commercial development that can reduce the risk of adversely affecting nearby intersections. For example, providing separate left-turn lanes for U-turn vehicles upstream or downstream of a signalized or an un-signalized intersection minimizes the need for diverted traffic to concentrate at intersections to make a U-turn. Additionally, providing dual left-turn lanes at intersections, with the inner-lane dedicated to U-turns can reduce the left-turn phase at a signalized intersection. Other alternatives include jughandle, bowtie, superstreet, continuous flow intersections, quadrant roadways and paired intersections. Chapter III will focus on these in further detail.

1.2 Objectives

The objectives of this research are to (1) evaluate the operational and safety effects of restricting the direct left turn from a driveway and (2) to evaluate alternatives that could be provided to accommodate the left turn deterred traffic in Ohio.

1.3 Thesis Organization

A literature review of related studies is presented in Chapter 2. Chapter 3 contains the results of a survey performed by the author of state agencies related to this topic. The operational analysis is contained in Chapter 4, while the safety analysis is found in Chapter 5. Finally, the conclusions and recommendations are the topic of Chapter 6.

CHAPTER II

LITERATURE REVIEW

In order to ascertain the state of knowledge and practice concerning the operational and safety effects of direct left turns, the author identified and reviewed pertinent literature. The author summarized the literature into two categories. The first category includes the studies that focused on the effects of restricted left turns, and the second category includes the studies that proposed and/or evaluated alternative movements for the left turn deterred traffic.

2.1 Effect of Prohibiting Direct Left-Turns

Because only a few studies have been undertaken to conclusively and comprehensively assess the effects of providing U-turns to replace direct left turns from a development, the operational and safety effects of providing U-turns as an alternative to direct left turns are still not clearly established. Most states have not enacted standards to provide U-turns as an alternative to direct left turns because of the lack of available data by which to conclusively set standards.

In recent years, the Florida Department of Transportation (FDOT) has been involved in several studies related to the safety and operational effects of restricting left turns. Florida prohibits any left turn exits onto major arterials through the use of median treatments. The practice in Florida is to provide mid-block U-turn lanes to accommodate the diverted left-turn volume.

Another study conducted in Florida found that by changing a direct left-turn from a driveway into a right-turn and then a U-turn reduced the accident rate at the driveway/roadway intersections by 22% at selected sites (Gluck, 1999). Earlier studies found comparable or shorter travel times when forcing right-turns followed by U-turns opposed to direct left-turns from driveways under heavy traffic volume conditions.

Another study also sponsored by the Florida Department of Transportation (FDOT) evaluated the safety and operational effects of replacing direct left turns from a driveway with a right turn plus a U-turn movement at varying distances from a driveway (Zhou, 2000). The study involved two sites and evaluated the right turn plus U-turn movement on arterials with speed limits of 45 mph and 50 mph, respectively, with conflicting traffic volumes of 4600 vehicles per hour on the arterial. The following traffic data was collected from these two sites: average travel time and waiting delay, traffic conflict rate, and speed reduction due to direct left turning traffic or right turn plus U-turning traffic.

After a preliminary analysis of the traffic data, it was concluded that the average waiting delay of the right turn plus U-turn movement was less than the average waiting delay of the direct left-turn movement. In addition, the conflict rate for right turn plus U-turn was much less than that of the direct left-turn.

The total travel time of direct left turns was found to be less than the right turn plus U-turn movements when the direct left turn volume was low (less than

50 vehicles per hour). The main advantages found for the right turn plus U-turn movement were reduced travel time and delay, under moderate and high volume conditions. However, the researchers observed some disadvantages, such as the waiting delay could be higher for low volume conditions and the longer travel distance may consume more fuel in a right turn followed by a U-turn than the direct-left turn.

Although the Florida Department of Transportation study may shed some light on the effects of restricting direct left turns for various volume conditions, consideration of the applicability of the results to Ohio must take into account the geometric and traffic conditions at these study sites. Traffic conditions such as speed and vehicle mix may vary from the conditions of these sites, so the findings of the study may be invalid for different geometric and traffic scenarios that exist in some locations in Ohio. Additionally, these studies did not consider the weaving problem that could exist when a vehicle turns right from a business and weaves over several lanes of traffic to get into the left turn lane, which may affect the safety of the roadway.

The Michigan Department of Transportation (MDOT) has prohibited direct left-turns at signalized intersections for more than forty years (Levinson, 2000). In order to accommodate the left-turn movement, a directional U-turn crossover downstream from the intersection is installed to improve safety and capacity along wide median-divided highways. This configuration permits two-phase traffic signal control, which potentially increases capacity and improves safety at intersections. This design is discussed further as an alternative in Section 2.3.

MDOT has installed the median U-turns along divided highways where the central median is at least 50 to 60 feet wide. The 60-foot median is required to accommodate WB-50 trucks, an intermediate semitrailer with a length of 55 feet, on a six-lane highway; the width can drop to 50 feet for an eight-lane highway. Another design consideration for the median U-turn is the location of the crossover. MDOT recommends placement 660'±100' from the signalized intersection. The indirect left-turn has led to lower accident rates, increased capacity, less total travel time, and improved signal coordination. Even though vehicles travel a greater distance to make an indirect left-turn through the crossover, it is offset by the reduced intersection delay therefore produces favorable results (Levinson, 2000).

According to a National Cooperative Highway Research Program (NCHRP) study, left turns cause many potential problems at driveways and intersections, such as increased conflicts, delays, and accidents (Gluck, 1999). They can also complicate traffic signal timing at the nearest intersection. According to this study, a right turn followed by a U-turn as an alternative to a direct left turn could reduce conflict and improve safety along arterial roads. This study found that although many states are using an alternative to the direct left turn, very few states have standards for the U-turn and handle them on case-by-case basis. The prohibition of direct left turns from existing driveways may transfer the displaced left turns to the nearest traffic signal controlled intersection unless intermediate U-turn lanes are provided. Therefore, the signal would have to provide a longer phase for the left-turn, sacrificing green time and capacity for the through movements.

This NCHRP report referred to simulation modeling done in Michigan that found that indirect left turns at unsignalized intersections may experience less delay than direct left turns depending on the arterial volume, and the additional travel distance involved. The simulation modeling also suggested that the provision of U-turns on the downstream side of signalized intersections and right-turn lanes on all approaches in conjunction with the prohibition of left turns can increase capacity by 14 to 20 percent over intersections where single or dual left turns are provided.

Several studies conducted in Florida and Michigan found that when direct left turns replaced indirect left turns (right-turn and U-turns), the accident rate was reduced on average about 20 percent (Gluck, 1999). In the Michigan study, 50 percent reduction in the accident rate was found for roadways with wide medians and directional crossovers compared to roads with two-way left turn lanes (TWLTLs).

Another NCHRP study evaluated the operation and safety effects and access impacts of the following mid-block left-turn treatments: the raised-curb median; the flush median with two-way left turn lane (TWLTL) delineation; and the undivided cross-section (Bonneson, 1997). This NCHRP study found that any left-turn treatments could function without causing congestion in arterial traffic movements with average traffic demands of 40,000 vehicles per day or less. The researchers also found that a wide range of traffic and geometric conditions, raised-curb median and two way left turn lanes (TWLTL), yield similar delays to arterial traffic flow.

The NCHRP Synthesis of Highway Practice 225 surveyed transportation agencies to identify various operational and safety implications for left turn treatments at intersections (1996). The survey in this study found that sixteen agencies use jughandles as an indirect left turn to relocate left turn movements. Other agencies commented that a jughandle is not a useful alternative for direct left turns as they can confuse drivers. The survey found that twenty-six state agencies use median U-turns as an indirect left turn option, while the general public and businesses initially favor the more direct left turn. Survey respondents also favored median U-turns over intersection U-turns.

A more recent study by Lei Xu compared the safety effects of right turns followed by U-turns and direct left turns (2001). The author collected data for 258 sample sites from seven counties within three FDOT counties. This study found that for 6-lane divided arterials with large traffic volumes, high speeds, and high driveway/side street access volumes, the implementation of a right-turn followed by U-turn compared to a direct left turn from a roadside facility leads to a 26.4 percent and 32 percent reduction in total and injury/fatality crash rates, respectively. For 4-lane and 8-lane arterials, implementing a right-turn followed by a U-turn compared to a direct left turn did not yield a statistically significant result due to the small sample size. The focus of the study was limited in scope as it did not consider the operational implications, such as delay on the mainline and driveway; driveway ingress and egress volumes; weaving patterns in the mainline and U-turns by large trucks.

In general, when a left turn is not permitted at an intersection, the U-turn movement must be accommodated by a median opening instead. The high speed of the conflicting traffic stream and low speed of the turning vehicle can combine to make the U-turn highly complex and risky. Therefore, a large gap in traffic must take place in order for the turning vehicle to feel safe in making the U-turn (Al-Masaaeid, 1999). This study examined the capacity of the U-turn movement at median openings of divided arterials.

The study resulted in two main findings. The conflicting traffic flow significantly influenced capacity and average total delay for U-turn movements at median openings. Both the conflicting traffic speed and average total delay were significant in estimating the critical gap for the U-turn movement.

2.2 Alternatives to Direct Left Turns

Joseph Hummer proposed several unconventional left-turn alternatives to relieve congested arterials (Nov. 1998). The jughandle alternative, shown in Figure 1, consists of ramps before the intersection diverging from the right side of the arterial to accommodate all turns from the arterial. These ramps are typically STOP-controlled for left-turns and YIELD-controlled for right turns. The ramp terminals should be several hundred feet from the main intersection, preventing blockage from queues from the signal on the cross street.

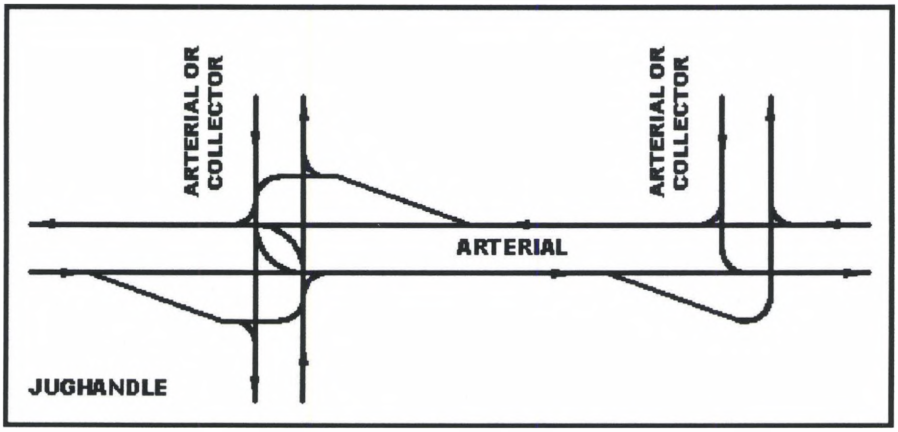


Figure 1: Jughandle Design (Hummer, Nov. 1998)

Although the jughandle design does not require a wide median, several disadvantages exist such as pedestrians having to cross ramps and the main intersection itself; additional right-of-way necessary for the ramps; additional construction and maintenance costs incurred for the ramps, and a lack of access to the arterial from areas next to the ramps. However, if jughandles were used as the primary means of making turns along a stretch of an arterial, driver confusion would be minimized. The New Jersey Department of Transportation has used jughandles for many years on miles of heavy-volume arterials. This option should be considered on arterials with high through volumes, moderate to low left-turn volumes, and narrow right-of-ways.

Another alternative for accommodating direct left turns is the continuous flow intersection. Figure 2 shows a schematic of a continuous flow intersection. Continuous flow intersections consist of a ramp to the left of the arterial upstream of the main intersection to handle traffic turning left from the arterial. This allows the arterial through traffic and traffic from this left-turn ramp to move during the same signal phase without conflict.

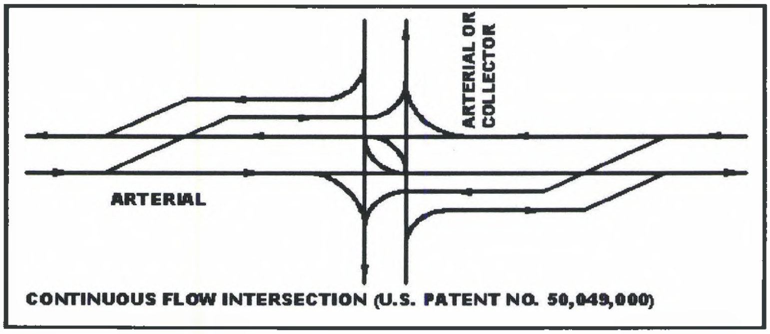


Figure 2: Continuous Flow Intersection (Hummer, Nov. 1998)

Francisco Mier of El Cajon, California holds a U.S. patent for the continuous flow intersection. The continuous flow intersection is useful where arterials have high through volumes and little demand for U-turns. An adequate amount of right-of-way must be available to construct the ramps. To date, no continuous flow intersections have been built anywhere. However, the State of New York has been considering the use of a continuous flow intersection for several intersections within New York City.

Another intersection design is the quadrant roadway intersection (QRI). As shown in Figure 3, the QRI utilizes an additional roadway in one quadrant of the intersection instead of allowing left-turn movements at the arterial/cross street intersection. This roadway should be at least a three lane cross-section to accommodate left turning at access points and storage for turns at the end of the roadway.

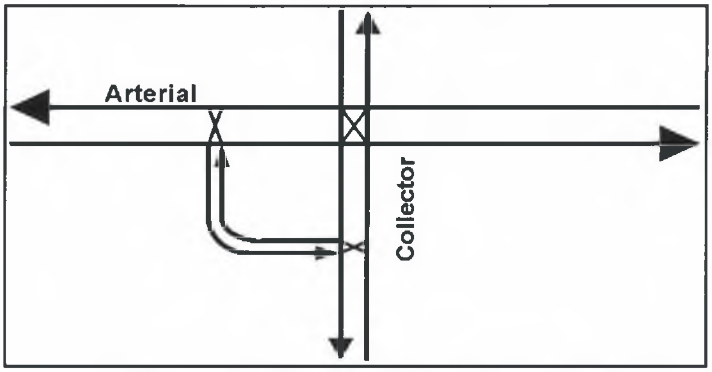


Figure 3: Quadrant Roadway Design

The arterial/cross street intersection can operate with a simple two-phase signal. However, all three signalized intersections must be coordinated to serve as one interconnected system. The secondary intersections would require three-phase signals, but the third phase would not affect through movement on the arterial.

Several design considerations are required for QRI. Loosely based on the AASHTO design manual, a 150-meter spacing for both QRIs was used in the analysis of the alternative (Reid, 2000). With the spacing, the area encompassed by the roadway is approximately 5.5 acres. Therefore, the use of the area must be considered since the quadrant roadway would be able to provide several access points, along with possibly right-in/right-out driveways located on the arterial and cross street. Advance signage is required to eliminate driver confusion when using this alternative.

The Michigan Department of Transportation (MDOT) has designed median U-turns for over 30 years with over 1,000 miles of roadway being served by them, the most in the United States. Figure 4 shows the Mid-block U-turn alternative (also known as Michigan-U).

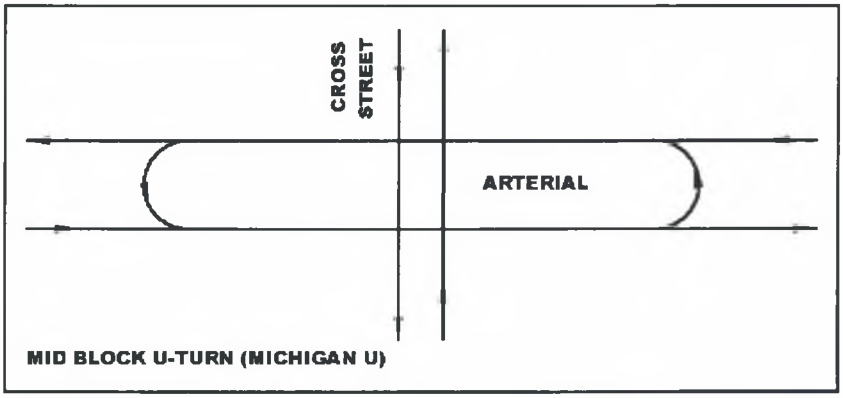


Figure 4: Mid-block U-Turn

The ideal location for a median U-turn is where high arterial volumes conflict with moderate or low left-turn volumes and any cross street through volumes. Several variations of this alternative could also be implemented (Hummer, Sept. 1998).

Another alternative to the direct left-turn is the bowtie, shown in Figure 5.

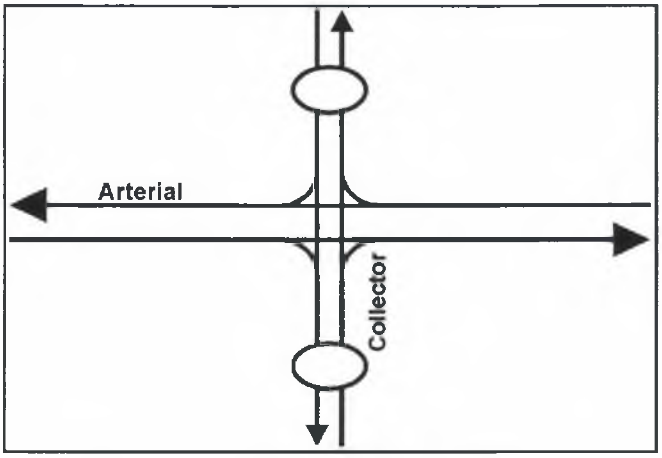


Figure 5: Bowtie

The bowtie alternative uses roundabouts on the cross street to accommodate left turns which are prohibited at the main intersection and allows a two-phase signal. Design considerations include the roundabout diameter, which can vary from 90 to 300 feet based on the speed of traffic, volume, the number of approaches, and the design vehicle. The roundabout should be 200 to 600 feet from the main intersection to avoid spillback, also keeping extra travel distance to a minimum. The median of the arterial can be narrow in this alternative (Hummer, Sept. 1998).

The use of roundabouts began in the 1930s in Germany. In the 1980s, German traffic professionals again began to design roundabouts to control traffic at intersections in both urban and rural settings after a period where other designs were favored. German professionals experimented with roundabouts and found that they can have positive benefits in relation to safety, quality of traffic flow and aesthetics. The German version tends to be a compact, single-lane roundabout, with an outside diameter of approximately 95 to 150 feet. Although roundabouts work well to slow traffic in urban areas, they may not be appropriate on rural highways or on higher speed roadways.

Roundabouts present both safety and environmental benefits. In the United Kingdom, France, and Germany accident rates have been significantly reduced by the use of roundabouts, 50 percent in urban areas and up to 80 percent outside of urban areas (Brilon, 1998). The reduction is due to the lower speeds at the intersection and the reduced number of conflict points. Environmental benefits include lower amount of impermeable surface due to the reduction in pavement area of the intersection and reduced air pollution due to less stopping and starting of the vehicles. In higher speed situations, modification of some design parameters would be required for the use of roundabouts.

CHAPTER III

SURVEY OF STATE AGENCIES

3.1 Survey Effort

In early October 2001, a survey was sent to a representative from each state's transportation agency. A copy of the blank survey form can be found in Appendix A along with the list of respondents that were received from twenty-four of the fifty states. The results of this survey serve as a best-practices inventory. Table 2 summarizes the responses received.

Table 1: Summary of Survey Results for Restricting Left Turns

States Responding to Survey	Policy/Guideline for Restricting Direct Left Turns		Study Conducted to Evaluate Operational or Safety Effects		Policy/Guideline for Accommodating Deterred Traffic		Design Standards for Restriction and/or Accommodation of Deterred Traffic	
	Yes	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**
Alabama		X		X		X		X
Arizona		X		X		X		X
Arkansas		X		X		X		X
Colorado	X		X			X	X	
Delaware		X		X		X		X
Indiana		X	X			X		X
Iowa		X		X		X		X
Kansas		X		X		X		X
Louisiana		X		X		X		X
Maryland		X	X		X		X	
Massachusetts		X		X		X		X
Michigan		X	X		X		X	
Minnesota	X		X			X		X
Missouri		X		X		X	X	
New Hampshire		X		X		X		X
New Jersey		X		X		X	X	
New York		X		X		X		X
Ohio	X			X	X		X	
Rhode Island		X		X		X		X
South Dakota	X			X		X	X	
Tennessee		X		X		X		X
Texas	X		X			X		X
West Virginia		X		X		X		X
Wyoming		X		X		X		X

3.2 Analysis of Survey Results

Of the responses received, only Colorado, Minnesota, Ohio, South Dakota, and Texas DOTs have implemented policies or guidelines that address the restriction of direct left-turns. Colorado has a regulation in place that addresses both new and existing roadways, based on the access classification of the road. Minnesota has been developing an access management manual and this issue will be addressed in the process. The Minnesota restrictions are based on traffic volumes, crash experience, the type of through road, and the distance from adjacent median openings, and pertain to both new and existing facilities. Ohio and South Dakota also have guidelines for restricting direct left turns, which are applicable to both new and existing roads. The basis for restrictions in these two states include access point density, speed limits, and the type of facility. Texas's guidelines apply to new and existing roads, but an include average daily traffic volume threshold (on the through road) of 20,000 to 25,000 vehicles to indicate the use of raised medians.

The majority of agency responses acknowledged a lack of formal policies or guidelines related to this topic. However, many states, including Indiana, Michigan, and New Jersey, responded that while no formal policy exists, left-turn restrictions from driveways are dealt with on a case-by-case basis determined by traffic and geometric factors. The New Jersey DOT makes decisions on left-turn restrictions based on through-traffic volume, traffic volume from the adjacent facility, crash experience, sight distance along the highway, and operational efficiency.

Table 2 summarizes the responses received from states regarding whether they have conducted recent studies on restricting left turns and accommodating the left-turn deterred traffic.

Table 2: Study Responses on Left Turn Restrictions

State Responding	Study Performed (who and when)	Elements of Study
Colorado	Colorado Access Control Demonstration Project, 1985	Safety and operational effects of medians
Florida	Safety impacts - completed Operational impacts - ongoing Both by Florida DOT and University of South Florida	Safety and operational impacts of direct left turn vs. right turn followed by U-turn at driveways
Indiana	Purdue University, approximately 4 years ago	Various forms of access control and tools
Maryland	JMT Consultants	Safety effectiveness of left turn restrictions
Michigan	Michigan DOT, December 1995	Directional crossovers, Michigan's left turn strategy
Minnesota	SRF Consulting, Dec. 2001	Access management issues
Texas	Texas DOT, Sept. 2002	"Techniques for Managing Access on Arterials"

Many states have conducted studies or stated that they are aware of current studies related to this topic. A recent research project at Purdue University, conducted in conjunction with the Indiana DOT, dealt with various forms of access control and its tools. A "Guide to Directional Crossovers, Michigan's Preferred Left Turn Strategy," developed in 1995 by the Michigan DOT, addresses the subject of restricting left turns. In Maryland, a study was conducted to evaluate the safety effects of restricting the direct left turn. It was found that restricting direct left turns was successful in reducing angle crashes at the driveway intersections and useful in places where signals should be avoided.

The Florida, Michigan, and Ohio DOTs were the only respondents to report a policy or guideline for accommodating deterred traffic from the restricted left turn. These guidelines are used for both new and existing roads. Michigan's Guide to Directional Crossovers supports the accommodation of deterred traffic. Currently in Ohio, left-turn deterred traffic is accommodated through the use of access roads, cross access to properties with full access, and access to adjacent streets. While the New Jersey DOT does not have a formal policy to accommodate left-turn deterred traffic, the use of U-turns is encouraged on divided highways and the use of jughandles on divided and undivided highways, especially with new construction. New Jersey implements signalized jughandles for U-turns and left turns. The Florida DOT recommends indirect left turns rather than direct lefts. They have median opening standards for both directional-type openings where only left-ins are allowed and for full median openings.

New Jersey also requires all new developments to operate at a non-failing level of service, LOS F. If it is found that the failure is due to left turns, then the state recommends that the development either be downsized or restricted to right turn only. If the left turn were restricted, the developer would be required to mitigate the impacts of a diverted trip at a location on the highway where alternative routes would be available. This concept is applicable in Ohio where a great deal of new development along major roadways contributes to poor performance of the roadway networks.

Many states reported the need to address warrants for left-turn restrictions and median closures and the resulting U-turn movements in the next update of their access management manual. These states reported one or more of the following factors should be considered in left-turn restriction warrants: through-traffic volume, traffic volume on the adjacent facility, access point density, crash experience, type of through-road, distance from adjacent median openings, and feasibility of U-turns at the median opening.

On the question of constraints to restricting left-turn movement from driveways, five states reported that business owners expressed concerns. One state reported a relatively straightforward policy of implementing restrictions to a new facility rather than removing access from existing roads. One state reported that in addition to the property owners' concerns, the additional right-of-way cost for providing alternatives for left-turn deterred traffic becomes a constraint for restricting direct left turns.

The Indiana DOT found that access control measures are rarely popular with persons and/or businesses directly affected by the measures, but often do not cause a problem when used in connection with new facilities. The Minnesota DOT observed that larger cities and counties support their access management manual, but smaller communities are less likely to feel the need for the guidelines, because they are primarily interested in economic development. However, the DOT has taken their access management manual on the road to meet with counties, cities, and planning districts to explain the applications and the affect they will have upon these agencies.

3.3 Survey Conclusions

The survey results revealed that very few states have formal policies regarding restricting direct left turns from a development and accommodating the resulting turn movement. Instead, most states handle this topic on a case-by-case basis. The most common factors influencing the decision to restrict a direct left turn movement is the through volume on the roadway and the crash experience at the site. In addition, several states realize the need for access management techniques and are in the process of studying and developing access management guidelines for their state. These states concluded guidelines need to address both new and existing facilities.

Currently, Ohio has some guidelines for restricting direct left turns based on access point density, speed limit of the road, and type of road. However, the deterred traffic is accommodated by the use of access roads, cross access to properties with full access, and access to adjacent streets. While, these measures suit Ohio at this time, ODOT feels there is a need for specific policies and measures to address this topic.

CHAPTER IV

OPERATIONAL ANALYSIS

4.1 Data Collection

Eight sites were chosen for evaluation, a combination of multi-lane divided, multi-lane undivided and two-lane roads. These sites served as a representative sample of Ohio's state routes. Unsignalized driveways that lead to major traffic generators, such as strip malls or super stores, and exit onto main roadways were additional study characteristics. Mainline speeds were between 35 to 45 mph. Table 3 summarizes the characteristics of each site.

Table 3: Site Characteristics

Main Road	Speed (mph)	No. of Lanes	Class	Driveway	Between	County
Alex Bell	35	4	Undivided	Cross Pointe Center	Far Hills and Loop Road	Montgomery
Lyons Road	45	4	Undivided	Walmart	SR 741 and Lyons Ridge Road	Montgomery
SR 725	45	4	Undivided	K-Mart	South Towne Center Drive and Kings Ridge	Montgomery
SR 741	45	4	Undivided	Contemporary Lane	Circuit City Drive and Prestige Plaza Drive	Montgomery
SR 725	45	4	Divided	Hooters Driveway	Paragon and Congress Park	Montgomery
West Broad	45	6	Divided	Westland Mall	Westland Mall Entrance and West Broad Plaza	Franklin
US 36	35	2	Undivided	Walmart, Kroger	SR 29 and Dugan Road	Champaign
US 22/SR 3	45	2	Undivided	Landen Square	Landen Drive and Columbia Road	Warren

Alex Bell is a multi-lane undivided roadway found in the City of Centerville. The study site consists of three unsignalized driveways and one signalized driveway that led to the Cross Pointe Shopping Center. Cross Pointe is a strip mall consisting of 30 stores. A sketch of the area is shown in Figure 6 below.

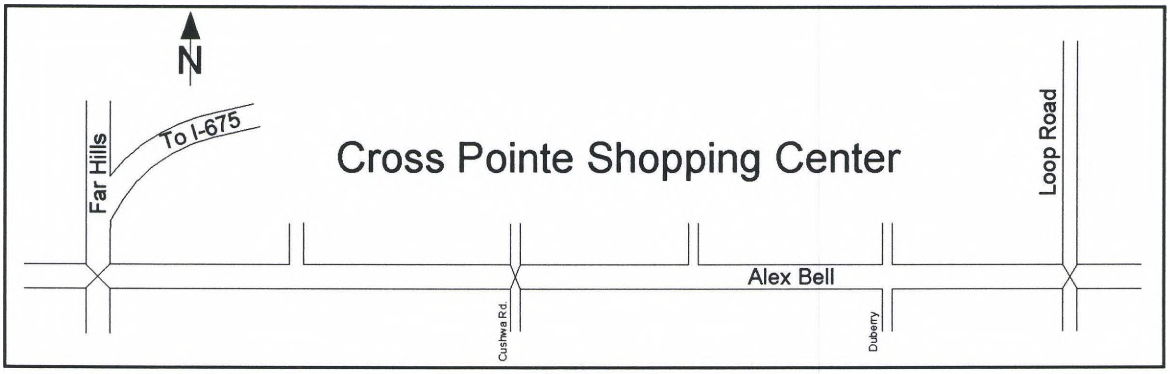


Figure 6: Alex Bell Diagram

The Lyons Road site is also a multi-lane undivided roadway, but is located in Miami Township near the Dayton Mall. The site consists of one unsignalized driveway leading to a Walmart, a fast food restaurant, and a small strip mall. Figure 7 depicts this study site.

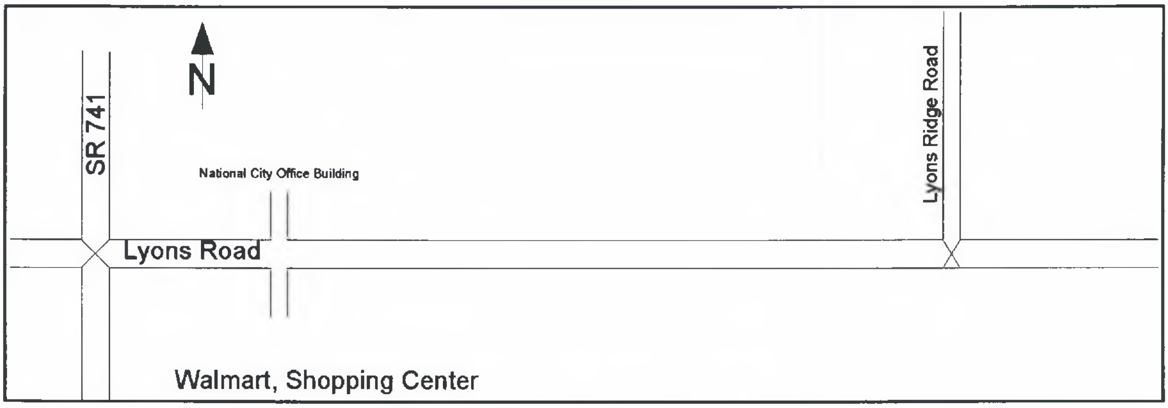


Figure 7: Lyons Road Diagram

The State Route 725/Kmart site is located in the City of Miamisburg, near the Dayton Mall. This site is also a multi-lane undivided roadway. The driveway studied leads to several restaurants, a Kmart store, and a small strip mall. A sketch of this site is shown in Figure 8.

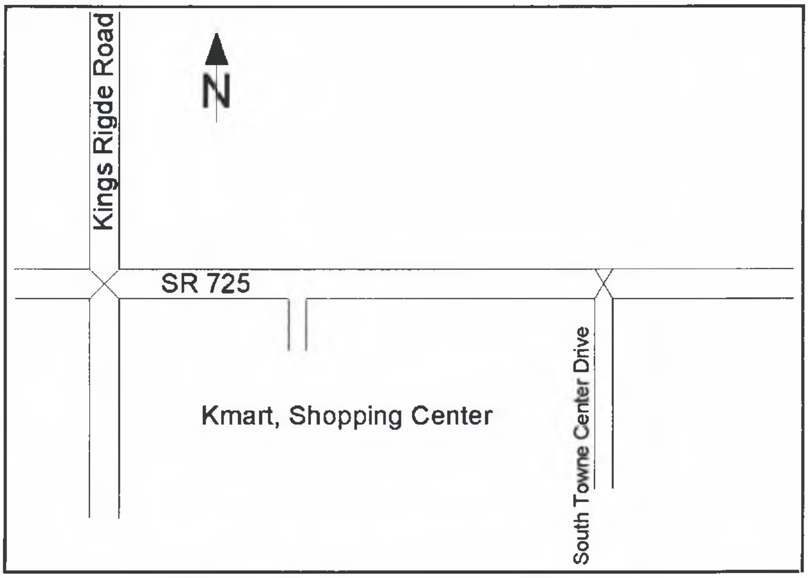


Figure 8: SR 725/Kmart Diagram

The last multi-lane undivided site is State Route 741 at Contemporary Lane and is located in Miami Township. Contemporary Lane leads to several hotels and a few restaurants across from the Dayton Mall. Figure 9 illustrates this site.

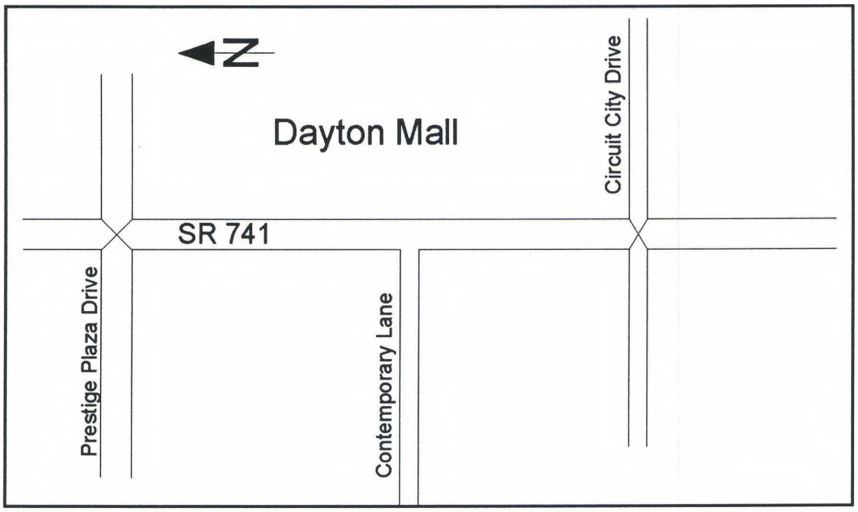


Figure 9: SR 741 Diagram

State Route 725/Hooters Restaurant site is a multi-lane divided site found in the City of Centerville. The driveway study leads to a Hooters restaurant, a Big Lots, and several other small stores. A diagram of this site is shown in Figure 10.

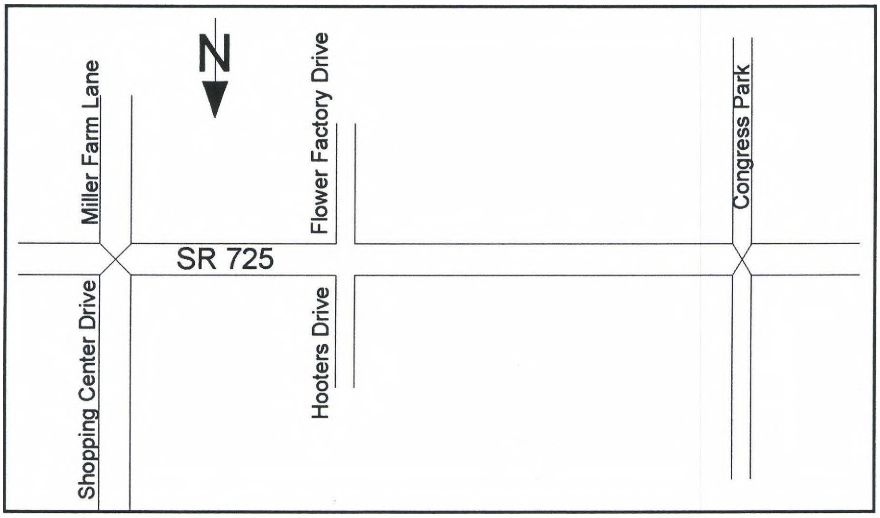


Figure 10: SR 725/Hooters Retaurant Diagram

The next multi-lane divided site is West Broad Street located in the City of Columbus. The driveway studied leads to a mall and strip mall. Figure 11 is a drawing of this site.

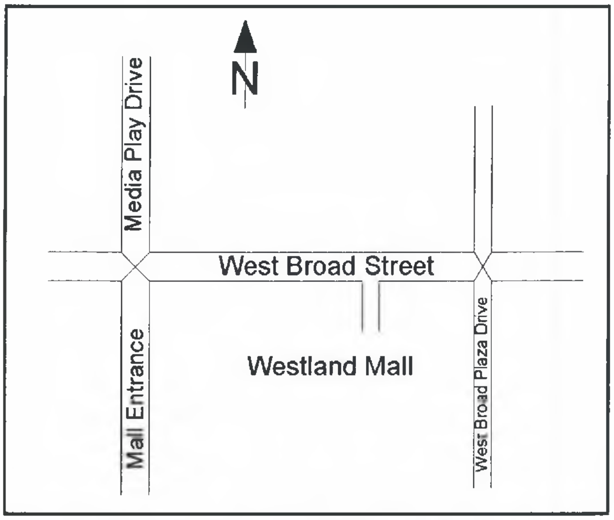


Figure 11: West Broad Diagram

The last two sites are two-lane roadways. The first is US 36 in Urbana and the driveways studied leads to a Walmart and Kroger. The second is US 22/SR 3 found in Twenty Mile Stand, north of Cincinnati. This driveway lead to a strip mall and two restaurants. These two-lane sites are shown in Figures 12 and 13 respectively.

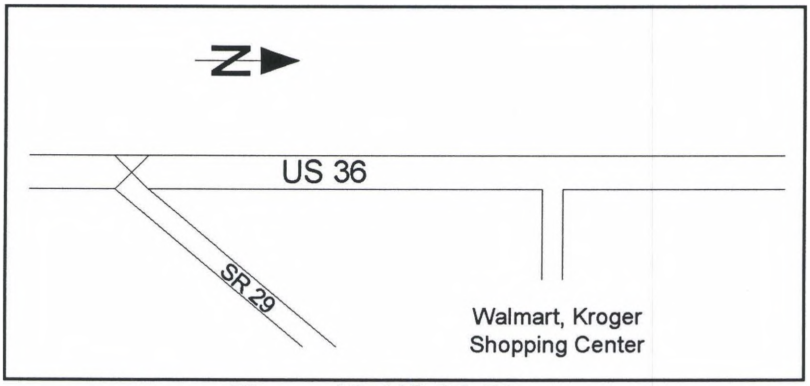


Figure 12: US 36 Diagram

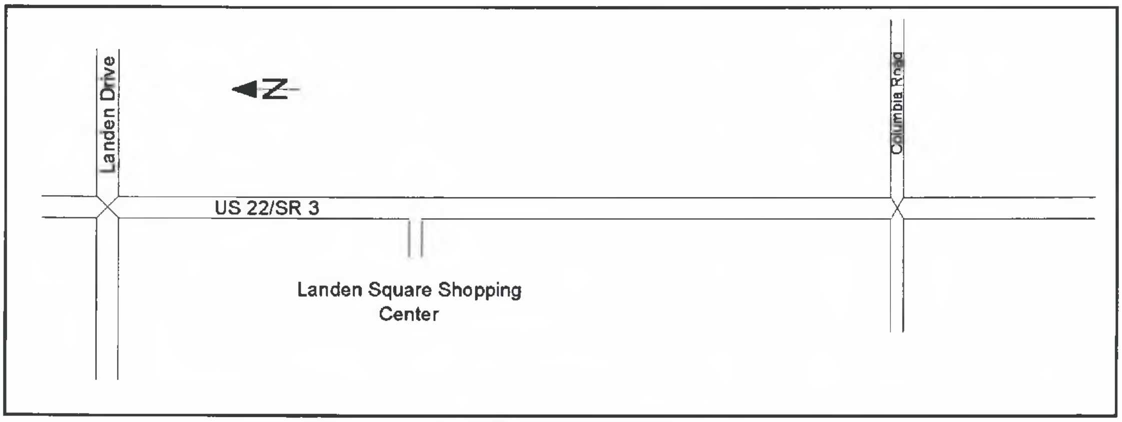


Figure 13: US 22/SR 3 Diagram

Geometric, traffic flow, and control data were collected for each study site. Geometric data included intersection configuration (pocket lanes, lane alignment, etc.), lane width, number of lanes, lane channelization, width of medians, and driveway location and spacing. Traffic flow data included volume counts by movements, average speed, travel times, and turn prohibitions. Traffic control data included type (actuated, semi-actuated or fully actuated), cycle length and phase length for non-actuated controllers, and phase settings and location of detectors for the actuated controllers. The study sites consisted of one or more driveways and the two signals surrounding the driveways.

Field data was also collected on travel time in the study corridors and queue length at intersections to verify the simulation output with the actual conditions. Travel time data was collected by driving a test vehicle at average speed in the corridor several times and queue length was found by field observations at the intersections. Field verification of the simulation models was required to ensure simulation results were valid.

4.2 Methodology

Simulation models were developed using the Federal Highway Administration (FHWA)'s Corridor Simulation (CORSIM) model for the eight representative corridors, corresponding to two-lane and multi-lane (divided and undivided) roads. CORSIM is a detailed microscopic simulation model that has undergone years of testing and evaluation by the FHWA, and has shown a high degree of correspondence to actual flow conditions.

Average delay per vehicle was selected as the measure to be used to assess the impact of the alternative strategies and identify the threshold values used for selection. Impacts were assessed at both a macroscopic (i.e., network) and microscopic level (i.e., for each link, intersection level and each movement within the intersection).

In addition, the networks were modeled using Synchro, signal timing software produced by Trafficware, to optimize signal timings for each alternative option, including U-turns at intersections and U-turns beyond intersections. The optimum signal timing for each alternative for each site was then input into the appropriate CORSIM model to effectively measure delays and average speeds.

4.3 Alternatives to the Direct Left Turn

Figure 14 shows a driveway schematic with the permitted left-out to arterial, left-in from arterial, right-in from arterial, and right-out to arterial. Based on the assessment survey results, literature review and discussion with experts, four alternatives to the direct left-turn were evaluated for this thesis.

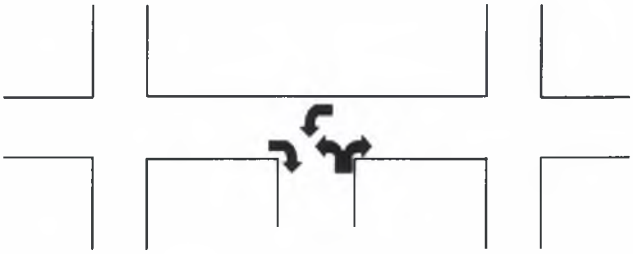


Figure 14: Existing Condition

In one alternative, shown in Figure 15, left turns were restricted with a right-in/right-out island and left-turn deterred traffic is forced to make a U-turn at the next intersection.

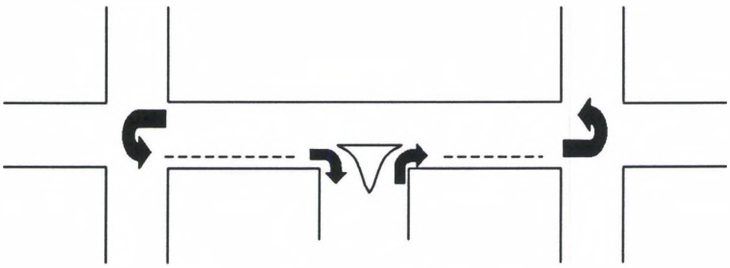


Figure 15: U-Turn at Intersection

The design of a right-in/right-out island and/or signage can eliminate the option of performing left turns at a driveway. In many instances, although traffic volume may justify signalization, signalization is not possible at driveways due to their proximity to the next signal. Shown below is another alternative to accommodate left-turn deterred traffic: U-turn beyond (Figure 16a) or after (Figure 16b) the intersection. U-turns could be permitted 600 to 660 feet before and after the nearest intersections to reduce the impact to the nearest intersection.

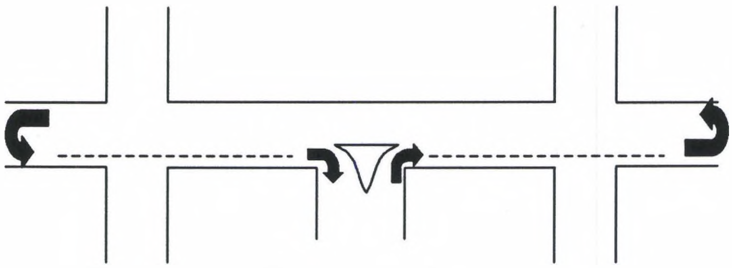


Figure 16a: U-Turn beyond Intersection

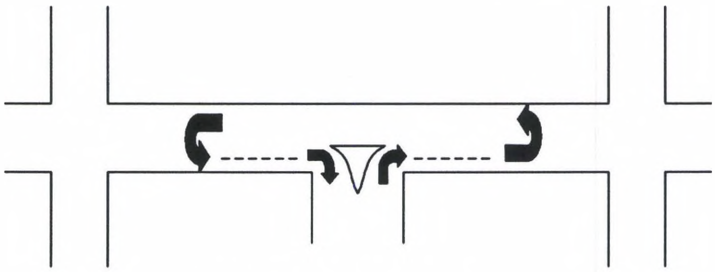


Figure 16b:U-Turn before Intersection

Another alternative for driveway left turn deterred traffic is a jughandle, shown in Figure 17, which consists of ramps located before the intersection that then diverge from the right side of the arterial and accommodate all turns (both left and right) from the arterial. This alternative was evaluated at three sites, one of each multi-lane undivided, divided, and two-lane.

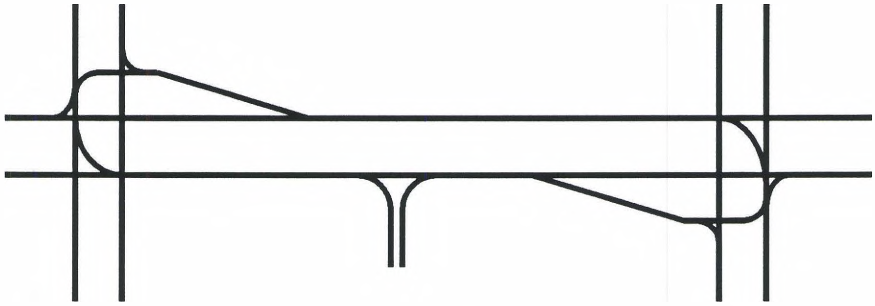


Figure 17: Jughandle Design

A driveway's left-turning traffic is forced to proceed to the next signalized intersection, follow the jughandle, and make a direct left turn at the signal. The ramps are typically STOP-controlled for left-turns and YIELD-controlled for right turns. The ramp terminals should be located several hundred feet from the main intersection, preventing blockage from queues from the signal on the cross street.

The concentrated left turn alternative was examined for one site, namely, the Alex Bell site. This site, shown previously in Figure 6, contains four driveways between two intersections: Alex Bell/Far Hills and Alex Bell/Loop Road. It consists of three unsignalized drives and one signalized drive. A scenario was examined in which all left turns were restricted from the driveways except from the Cushwa Road driveway, which is the signalized driveway. Under this scenario, all left-turn restricted traffic from the three other driveways moved to this signalized driveway to make direct left turns.

4.3.1 U-Turn Alternatives

Three major operational alternatives have been evaluated for all sites:

- Case 1: No restriction of direct left turns from or to driveways,
- Case 2: No direct left turns in or out of driveways and diverted traffic makes a U-turn at the next intersections, and
- Case 3: No direct left turns in or out of driveways and diverted traffic makes a U-turn at mid-block (before or after the intersection).

First, the existing condition (Case 1) was modeled and evaluated. Next, the network was modeled again for Case 2, allowing only right-in, right-out traffic at the driveway and allowing U-turns at the surrounding signals. Last, the network was modeled for Case 3, allowing only right-in, right-out traffic at the driveway, restricting U-turns at the surrounding signals, and providing mid-block U-turns before or beyond the signalized intersections. Each network was simulated with Synchro to determine optimum signal timing for each case, then in CORSIM to compute the delay per vehicle.

4.3.1.1 Impacts of Changes in Mainline Volume

Figure 18 shows the changes in total network delay with the increase in the mainline volume at multi-lane divided sites.

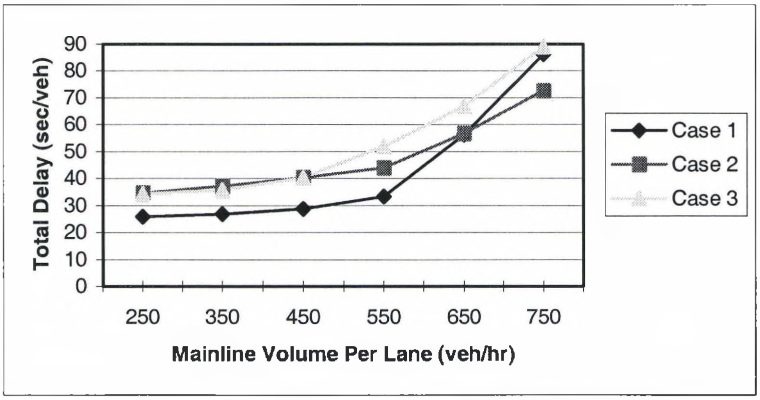


Figure 18: Average delay at mainline volumes (per lane) - multi-lane divided

The driveway volume was held constant while changing the mainline volume. As shown in the figure, Case 1, where no restrictions on left turns were implemented, operationally outperformed the cases with left turn restrictions at the driveways as long as the mainline volume per lane was less than 650 vehicles per hour. Case 2 becomes the preferred alternative after the volume threshold of 650 vehicles per hour per lane is reached.

Figure 19 shows the changes in total network delay with the increase in the mainline volume at a multi-lane undivided site.

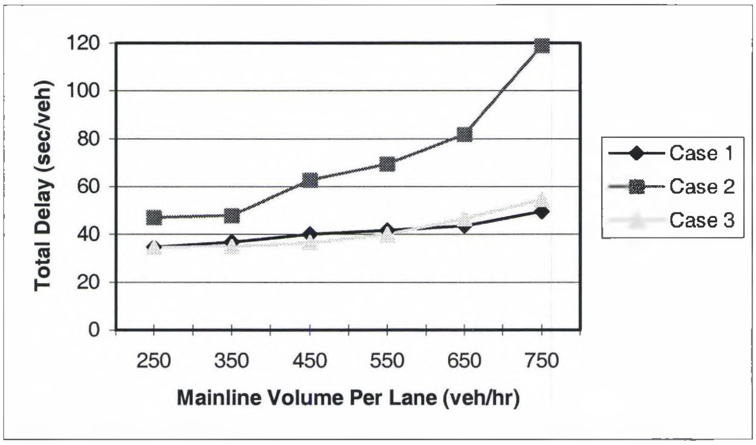


Figure 19: Average delay at mainline volumes (per lane) - multi-lane undivided

The figure shows that with increased mainline volume, the increase in average delay was similar for Cases 1 and 3. On the other hand, the increase in delay for Case 2 abruptly increased with the increase in mainline volume. The increased delay due to left-turn restrictions appears to be much more significant for undivided compared to divided highways.

Figure 20 shows the changes in total network delay with the increase in the per-lane volume at two-lane roads.

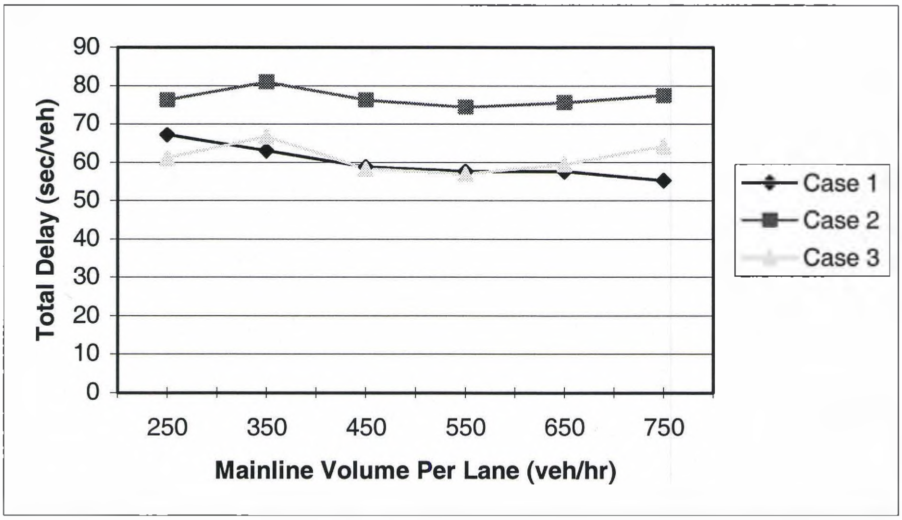


Figure 20: Average delay at mainline volumes (per lane) – Two-lane

Case 1 and 3 performed similarly for different volumes. Case 1 performed slightly better after the volume threshold of 650 vehicles per hour per lane. Overall Case 2 performed at an inferior level than Cases 1 and 3.

4.3.1.2 Impact of Driveway Volume and Mainline Volume

Figures 21 and 22 show the driveway volume versus average network delay to intersection delay for a multi-lane divided and multi-lane undivided site. The figures show an increase in mainline volume plays a greater role than an increase in the driveway volume in terms of delay.

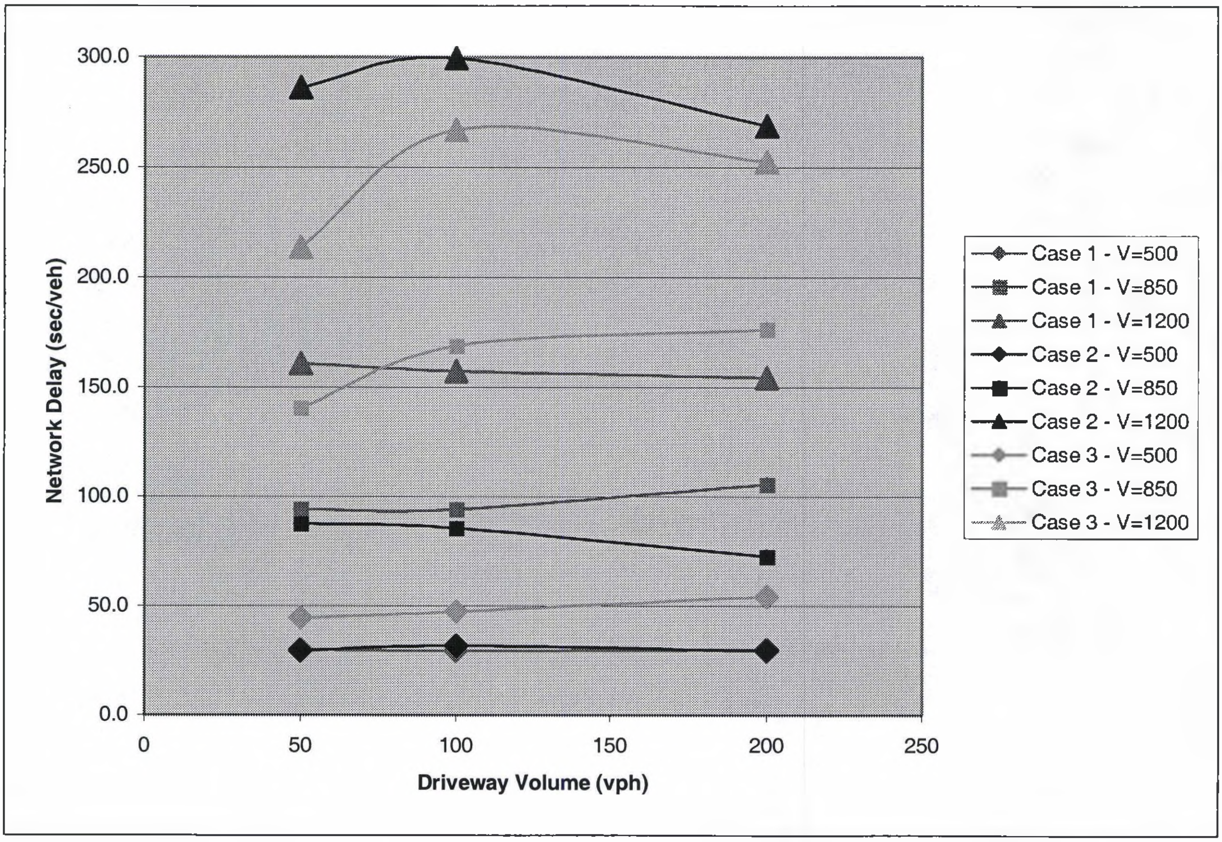


Figure 21: Driveway Volume vs. Delay for Multi-lane Divided (Hooters Drive)

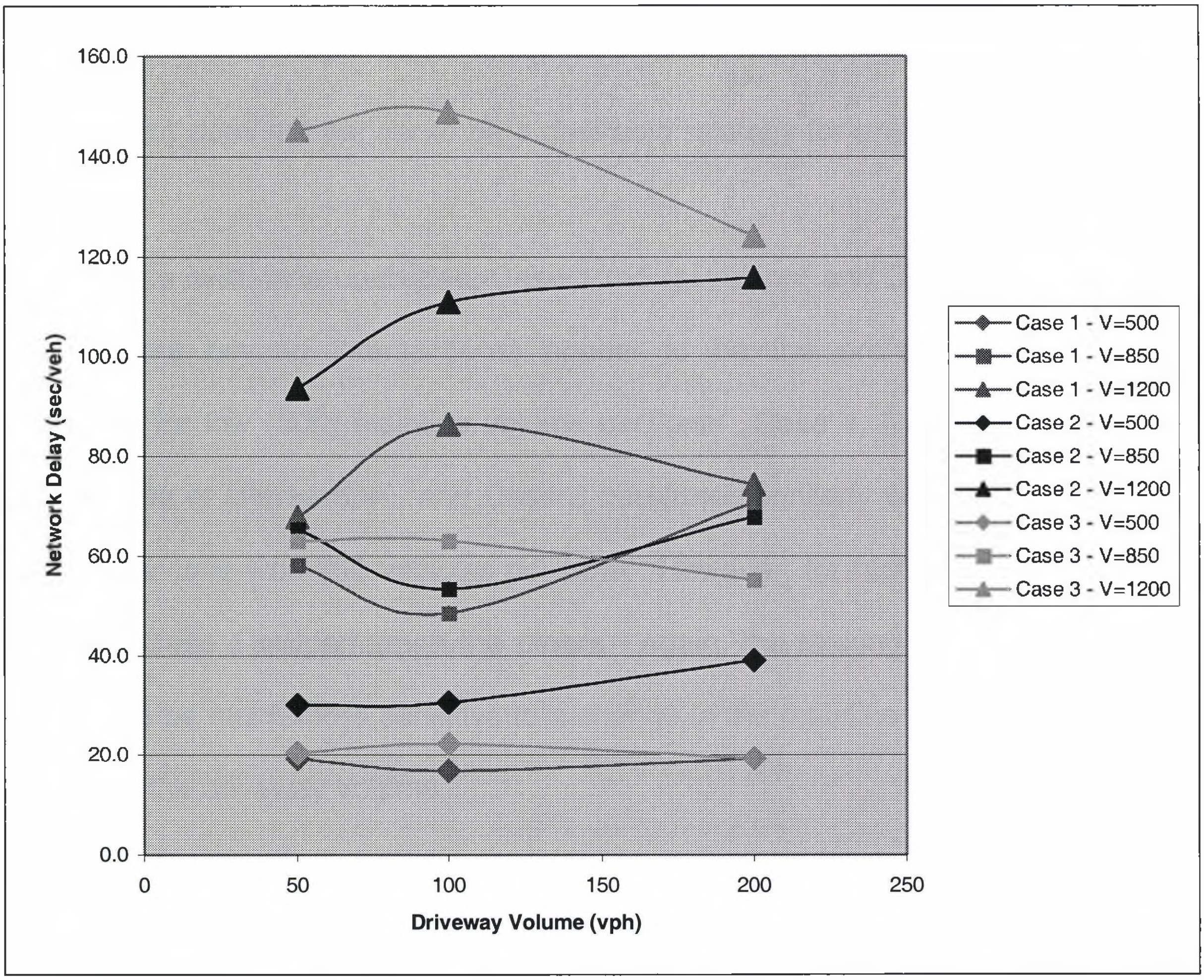


Figure 22: Driveway Volume vs. Delay for Multi-lane Undivided (K-Mart Drive)

For multi-lane divided, Case 1 (no restriction) and Case 2 (restriction and U-turns at intersections) appear to be the preferred operational strategies, depending upon the mainline volume. For low (500) mainline volume per lane, Case 1 and Case 2 performed equally. Case 2 performed slightly better for medium mainline volumes (850), and for high (1200) volumes per lane, Case 1 outperformed the others. In addition, the ranking of the strategies appears to be much more sensitive to change in mainline volume than to change in driveway volume. For multi-lane divided, Case 3 (restriction and U-turns beyond

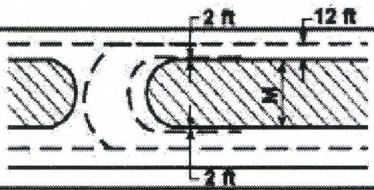
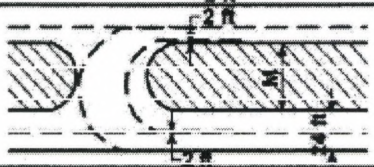
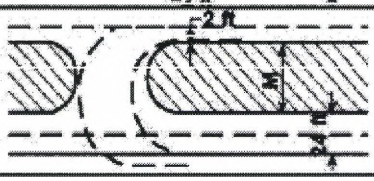
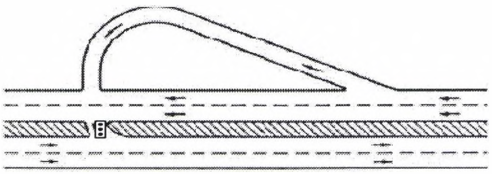
TYPE OF MANEUVER		M - MIN. WIDTH OF MEDIAN (ft) FOR DESIGN VEHICLE						
		P	WB-40	SU	BUS	WB-50	WB-60	TDT
		LENGTH OF DESIGN VEHICLE (ft)						
		19	50	30	40	55	65	118
INNER LANE TO INNER LANE		30	61	63	63	71	71	101
INNER LANE TO OUTER LANE		18	49	51	51	59	59	89
INNER LANE TO SHOULDER		8	39	41	41	49	49	79

Figure 23: Minimum Width Design for U-turn (AASHTO 2001)

However, when there is no supporting access system for large vehicles, they must be accommodated at the U-turn location. This situation will probably only occur at or near truck facilities, major industrial areas, or truck staging areas. The movement could be accomplished in one of two ways. Both options are illustrated in Figure 24.


Option A

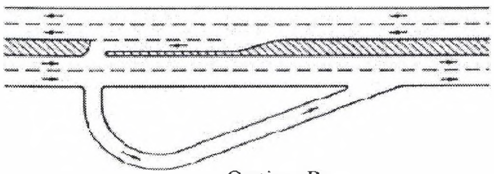

Option B

Figure 24: Options for Accommodating Large Vehicles or Narrow Medians

As shown in Figure 25, compared to the other cases, the concentrated left-turn at a particular driveway proved to be a worthy alternative.

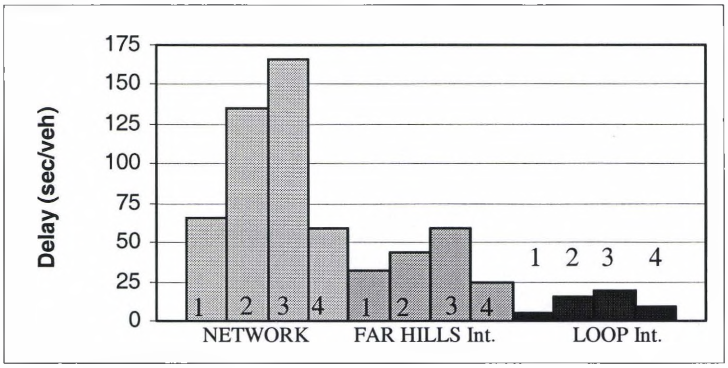


Figure 25: Operational Impacts of Various Strategies on Alex-Bell Road

In the above figure,

- Case 1 is no restriction of direct left turns
- Case 2 is left turn restriction at the driveways and diverted traffic makes U-turn at the next intersection
- Case 3 is left turn restriction at the driveways and diverted traffic makes U-turn beyond intersection
- Case 4 is the concentrated left turn at one signalized intersection.

Based on this assessment, at many sites where multiple driveways exist, restricting the direct left turns from all but one driveway and allowing this traffic to make direct left turns at the signalized intersection may be operationally advantageous and more cost effective than other options.

4.3.2.2 Jughandle Alternative

The jughandle alternative was also evaluated against the initial three alternatives in the study for one multi-lane divided site, one multi-lane undivided site, and one two-lane road. Figures 26, 27, and 28 compare the average delay for these sites, respectively.

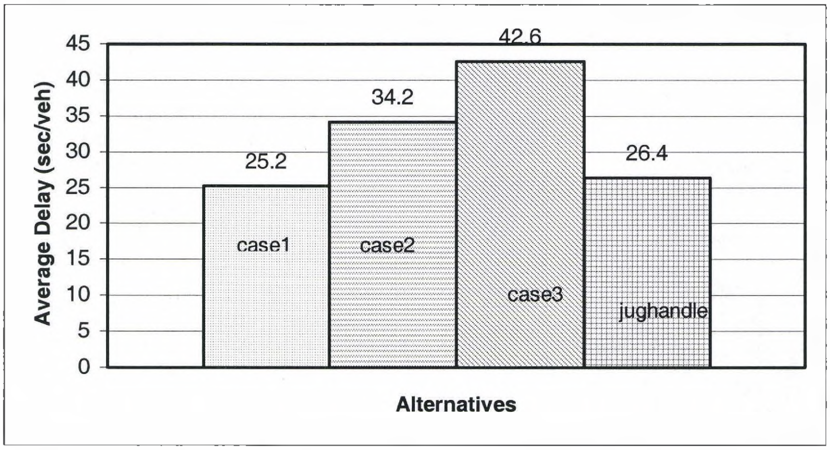


Figure 26: Delay/Vehicle for Three Cases, Jughandle - Multi-lane Divided Site

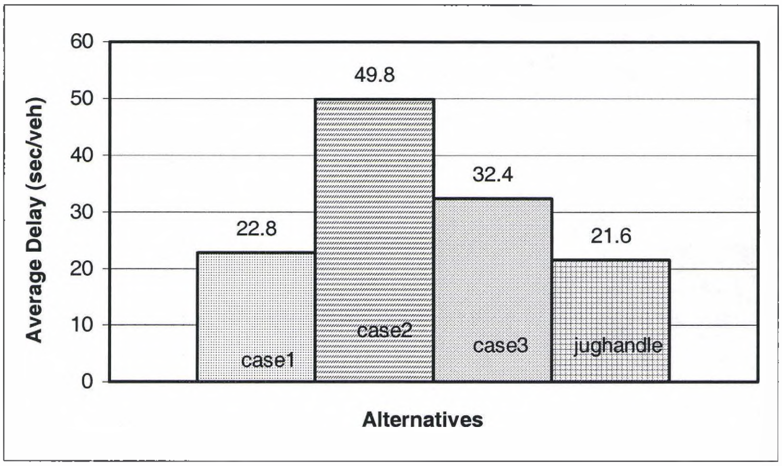


Figure 27: Delay/Vehicle for Three Cases, Jughandle - Multi-lane Undivided SIte

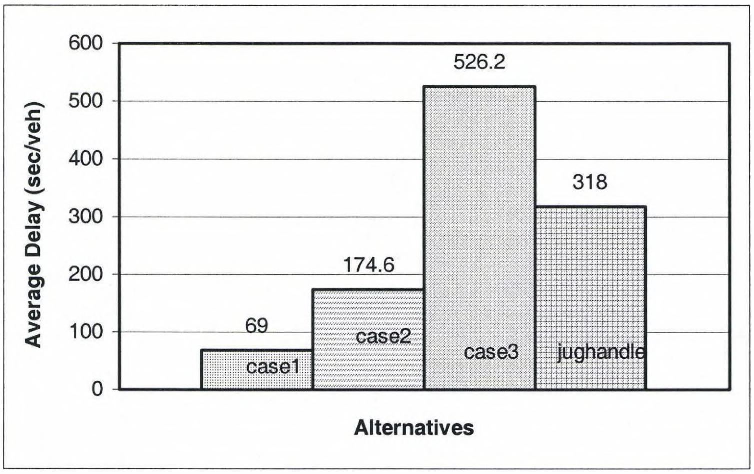


Figure 28: Delay/Vehicle for Three Cases, Jughandle - Two-Lane SIte

As shown in Figures 26 and 27, the performance of the jughandle alternative was superior to the other three alternatives for multi-lane undivided highways and similar to Case 1 for multi-lane divided roadways. For two-lane roads, Figure 28, the U-turn and jughandle did not perform well due to high volume of opposing traffic. Since the existing volume at the two-lane site was much higher than the volume threshold shown in Figure 20, operationally the performance of the alternatives was worse than the existing condition with no restrictions on the left turn.

Existing high volume to capacity (v/c) ratios at the nearest signalized intersection negetively impacted the alternatives for two-lane roads where additional demands were placed on signal capacity. For multi-lane divided and undivided sites, a key factor is the volume to capacity ratio of the through and left-turn movements in the approach of the left-turn deterred traffic. With reasonable existing v/c ratio (on an average below 0.5), the alternatives did not significantly degrade the operational performance for the U-turn and jughandle alternatives.

CHAPTER V

SAFETY ANALYSIS

Safety analysis for this project consisted of three parts: an analysis of the accidents and accident rates at the current sites, a review of published studies performed by other states, and communication with other state transportation agencies.

5.1 Analysis of Current Sites

5.1.1 Data Collection

Three years of crash data was collected for each site. The most current data available for each site was obtained and used for analysis. Table 4 shows each site, the specific years of data collected, and where the data was obtained.

Table 4: Accident Data Characteristics

Type of Site	Multi-lane Undivided				Multi-lane Divided		2-Lane	
Site	**Lyons**	**Alex Bell**	**SR 725**	**SR 741**	**SR 725**	**West Broad**	**US 36**	**US 22**
Years of Accident Data	1997-1999	1998-2000	1999-2001	1999-2001	1999-2001	1999-2001	1999-2001	1999-2001
Data Collected From	ODOT	City Engineer Report	Accident Reports	Accident Reports	Accident Reports	ODOT	Accident Reports	Accident Reports

Data collected from ODOT came from accident reports generated by the safety department. For the Alex Bell site, the City of Centerville supplied collision diagrams for the site. The remaining accident data was gathered from visiting various police agencies and examination of accident reports for the years desired.

5.1.2 Methodology

Once the crash data was obtained from various sources described above, the crashes were plotted for ease of analysis. The accidents were then categorized by type: rear end, sideswipe, angle, and left-in/left-out (for the driveways). Left-turn crash rates per million vehicles entering the un-signalized driveway intersection were computed for each site.

5.1.3 Analysis of Existing Conditions

As described in the previous section, eight sites were selected representing, multi-lane undivided, multi-lane divided and two-lane sites. Table 5 summarizes relevant accident data.

Table 5: Sample Sites Crash Summary

Type of Site	**Multi-lane Undivided**				**Multi-lane Divided**		**2-Lane**	
Site	**Lyons**	**Alex Bell**	**SR 725**	**SR 741**	**SR 725**	**West Broad**	**US 36**	**US 22**
Left Turn Crash % (Left Turn Crashes/Total Crashes)	50%	15%	26%	11%	40%	21%	40%	100%
Left Turn Crash Rate (# Accidents per Million-Entering Vehicles)	49	25	101	16	113	54	125	58

The left-turn crash percentage is a measure of the number of crashes related to vehicles making left-turn movements into and out of the driveway at hand divided by total crashes at the driveway location. The crash rate is a measure of the amount of crashes related to vehicles making left-turn movements into and out of the driveway at hand divided by total number of vehicles entering the driveway-mainline intersection. In many sites, the left-turning crashes were a high percentage of total crashes, which illustrates the value of reducing left-turning vehicles at un-signalized driveways.

5.2 Expected Impacts

Due to the lack of applicable sites in Ohio, other states were contacted about their findings on the impacts of restricting left-turn and providing alternative movements to the left-turn deterred traffic. Additionally, the recent studies were consulted to estimate expected reduction.

A conflict is a point where two vehicle paths cross. Figure 27 shows conflict points at an unsignalized driveway with no-turn restrictions. As shown in the figure, with all permitted turns from the driveway, nine conflict points exist. Figure 28 shows the driveway with right-in right-out restriction and a mid-block U-turn. Without the direct left in and left out, these conflict points are significantly reduced. Limiting the conflict points and separating them improves safety, as it eliminates the risk of crashes.

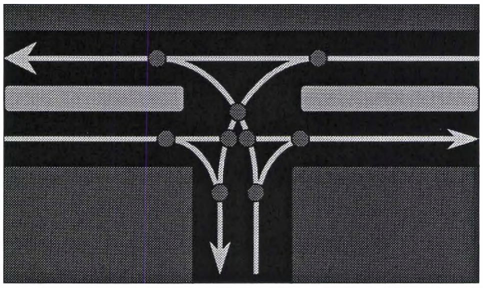


Figure 29: Conflict Points at a Non-restricted Driveway

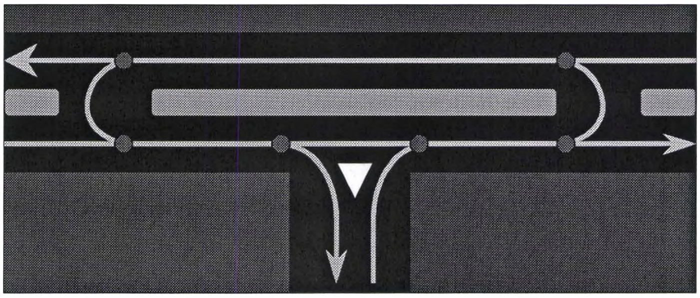


Figure 30: Conflict Points at a Restricted Driveway with a Mid-block U-turn

Recent studies based on actual conflict evaluation (observation of conflict-related measures in the field) between a direct left-turn and right-turn followed by a U-turn found a reduction in actual conflicts. The primary conflicts caused by the direct left-turn include those with the two-direction major road traffic and also with all other movements at the median openings for the driveway. In the case of direct left-turns, drivers may get impatient and aggressive with long waiting delay and move to the median opening without yielding to the major road through or left-turn in traffic.

The Colorado Access Control Demonstration Project of 1985 examined the safety and operational benefits of medians. It reported to the US Congress that the benefits of medians are excellent and U-turn crashes along corridors with medians are minimal or nonexistent. However, in order for the U-turn movement to remain safe and operational, it must be used in conjunction with a strong supporting local street system. Poor supporting local street systems cause poor circulation and force motorists to make unusual, often unsafe, and even illegal movements to allow drivers to get where they want to go.

An access management paper published by the Florida DOT states that their most recent research shows that by encouraging right turns followed by U-turns, the total crash rate is reduced by 18 percent and the injury crash rate is reduced by 27 percent (FDOT Access Management Brochere). They also acknowledge a strong relationship between access points per mile and the crash rate. Therefore increasing the spacing between access points using right-in/right-out driveways with median U-turns reduces conflicts, in turn causing fewer collisions.

A Florida Department of Transportation sponsored study found that direct left turns led to more conflicts than right turns followed by U-turns (Dissanayake, 2002). The site characteristics included: major arterial, three to four lanes in each direction and speeds greater than or equal to 45 mph. This study found that traffic conflicts were significantly reduced for a site where a direct left turn from a driveway was converted to a right turn followed by a U-turn. Comparing the average number of crashes and crash rates, it was and found that right turns followed by a U-turn are much safer for high volume, multi-lane major arterials.

The impacts based on the survey were evaluated and compared with information from other state agencies, which have evaluated safety impacts of these alternatives. It should be noted that when the volume is shifted through left-turn restrictions to the nearest intersection, additional conflict occurs between vehicles executing the U-turn and vehicles making right turns from opposing or adjacent streets. Restricting right-turn on red for opposing streets could eliminate these conflicts.

Due to a lack of appropriate sites in Ohio, it was not possible to perform a before and after study to evaluate the safety impacts of restricted direct left turn access. However, one site allowing only right-in/right-out access along a stretch of roadway is currently under construction. In Perrysburg, Ohio, US 20, east of the I-75 interchange, construction is under way to restrict direct left turns and encourage U-turns at the intersections. This site should be used for further study to evaluate the safety effects of restricting the direct left turns. ODOT's District 2, which is completing the project, was encouraged to utilize this alternative after the success of the mid-block U-turn bays installed along another section of US 20. This section of roadway was converted from a two-lane section to a four-lane with mid-block U-turn bays in the mid 1970's. It is contended that the performance of this section of road has been exemplary, as expected. Accident rates are low and delay is minimal. Therefore, the use of right-in/right-out restrictions followed by U-turn movements is highly encouraged (Jones, 2002).

Although the operational analysis conducted for this study provided mixed results for the U-turn alternatives, other recent studies suggest a positive safety effect from implementing U-turns at intersections or at mid-block locations. Roadway locations and conditions that could benefit in terms of safety, through restriction of left-turns and providing mid-block or intersection U-turns are listed below:

- Corridors through or adjacent to a major commercial or residential development
- Speed limit between 40 to 55 mph
- Major arterial with 4, 6 or 8 lanes
- ADT 30,000 to 40,000 vehicles

CHAPTER VI

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

6.1 Summary

Eight sample sites, consisting of multi-lane divided, multi-lane undivided, and two lane roads, were chosen for evaluation of alternatives to the direct left turn from driveways. For the operational analysis, two U-turn alternatives were examined: allowing only right-in, right-out traffic at the driveway and allowing U-turns at the surrounding signals and allowing only right-in, right-out traffic at the driveway and allowing U-turns before or after surrounding signals. In addition, two other alternatives were evaluated, the jughandle and concentrated left turn. Each network was modeled in CORSIM to find delay per vehicle, as well as in Synchro to adjust the signal timing to optimum for each case.

The effect of the changes in the mainline volume, as well as changes in the driveway volume, was examined. Overall, the change in the mainline volume had a much more significant impact on the delay per vehicle. However, no conclusive results were found to determine when a restriction for a direct left turn shall be put in place or which alternative shall be implemented.

Crash data was obtained for each sample site and analyzed to find the left turn crash rates at the driveway locations. The percentage of left turn crashes at many of the sites was high, which illustrates the value of reducing left turning vehicles. In addition, recent studies were found that conclude a right turn followed by a U-turn movement is safer than the direct left turn.

6.2 Conclusions

Very little operational difference was found between no restrictions on direct left turns versus restrictions with a U-turn alternative movements considered in this study. For some volumes of the mainline, the delay was less for one of the U-turn alternatives compared with the non-restricted case, however no definite trends were apparent. It was evident from these findings that proposed alternatives must be evaluated on a site-by-site basis.

Based on the analysis the jughandle design may be an alternative for multi-lane divided and undivided. When a sufficient median width is not available for a median U-turn, the jughandle may be an option, although, it would require right of way near the surrounding intersections in order to build the ramps. In addition, the jughandle is not in common use in Ohio, so it would require driver education and signage to implement such a design.

The concentrated left turn has been shown to be an excellent solution for existing conditions as well as new development. For an existing site if there is the potential for several driveways to lead into one development with sufficient traffic flow through the facility, left turns could be restricted to all but one intersection through the use of right-in/right-out islands and signs. In the case of a new development, traffic circulation through the parking lot could be designed to allow vehicles to move easily to the signalized driveway to minimize any extra distance to be traveled. The signalized intersection timing would have to provide sufficient green time to the driveway so the delay would be minimal for the left turning vehicles. This option not only minimizes the delay for the exiting vehicles, but also for those entering the facility as well as the through traffic on the mainline.

6.3 Recommendations

Since the operational analysis from the study sites was inconclusive on suggesting a particular U-turn treatment for a left turn restriction, further study of other influencing factors must be performed before parameters or standards could be developed on this issue. The surrounding signal capacities may provide some additional insight into the effects of restricting direct left turns. Consequently, when considering an alternative to the direct left turn, models should be run to evaluate the signal capacity of the signals surrounding the driveway before deciding upon an alternative.

The following recommendations have been put forth as a result of this study:

- Continue research on this topic in order to establish trends related to the surrounding signals and the signals throughout the corridor
- Assess and use alternatives to full movement turns (right-in/right-out and left-in/left-out) on a case-by-case basis only
- Conduct before-and-after safety studies on sites where alternatives have been implemented in Ohio.

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APPENDIX A

November 22, 2002

«FirstName» «LastName»
«Company»
«Address1»
«Address2»
«City», «State» «PostalCode»

Dear «FirstName» «LastName»:

We are performing a study titled "Evaluating the Effects of Prohibiting Left Turns and the Resulting U-turn Movements" for the Ohio Department of Transportation.

The purpose of this study is to assess the operational and safety benefits of prohibiting direct left turns and providing u-turns or other credible alternatives for the diverted traffic. The results of this study will serve as a resource for ODOT in establishing a statewide standard regarding the management of left-turn deterred traffic on the mainline facility and adjacent driveways and intersections.

Please forward the questionnaire to the appropriate personnel in your office. We would be grateful for your help with our study. Your response by October 31, 2001 would be greatly appreciated. Please let us know if you are interested in receiving a copy of our report once it is completed.

If you have any questions, please call me at 937-229-2984 or e-mail me at mashrur.chowdhury@notes.udayton.edu.

Regards,

Mashrur (Ronnie) Chowdhury, Ph.D., P.E.
Assistant Professor

Survey for the Study
"Evaluating the Effects of Prohibiting Left Turns and the Resulting U-Turn Movement"

As part of the Ohio Department of Transportation (ODOT) Access Management study titled "Evaluating the Effects of Prohibiting Left Turns and the Resulting U-Turn Movements," we are conducting this survey to assess the operational and safety impacts of prohibiting direct left turns from a roadside facility and providing u-turns or other credible alternatives for the diverted traffic. We would be grateful if you would take few minutes of your time to respond to the following questionnaire. Your response by October 31, 2001 would be greatly appreciated.

Please provide the name of the person completing this questionnaire, or the person who may be contacted in your agency to obtain any follow-up information:

Name ____
Title ____
Agency ____
Address ____
____
Phone ____
Email Address _______________________________________

1. Do you have a statewide policy/guideline for restricting direct left-turns from a roadside adjacent facility? Yes _____ No_____

Is the policy/guideline applicable to: Existing Roads______ New Roads _____ Both______

If a policy/guideline exists, what is the basis for restricting left-turns (Please mark the appropriate criteria from the following)?

Through Traffic Volume________
Traffic Volume on the Adjacent Facility______
Access Point Density_________
Speed Limit on the Road______
Crash Experience ________
Type of Through Road (e.g., rural principal arterial, urban principal arterial, etc.)___________
Others (Please Specify) ______________

2. Has your agency conducted any study to evaluate the operational (such as delay, speed, etc.) and safety (crash rate, conflicts, etc.) effects of prohibiting direct left-turn from a facility? Yes____ No____

If yes, what were the major findings of the study? (Please use a separate sheet if necessary.)

____

____

How can we obtain a copy of the study? ______________________________

____

Are you aware of any other studies or reports on the effect of prohibiting direct left turn from a roadside facility? Yes____ No____

If yes, please provide any information or reference you have on the report/study.

____

____

3. Do you have a policy/guideline for accommodating the left-turn deterred (or diverted) traffic? Yes ___ No____

If yes, please indicate whether you use any of the following measures and if applicable, under what traffic or other conditions (traffic speed on the roadway, volume on the facility and the roadway, etc.):

U-turn______ Conditions_________________________________

Jug-Handle_____ Conditions_______________________________

Others (please provide a sketch if possible) ______________________

____

Do you have any design standards/recommendations (acceleration lanes, median geometry, etc.) for restricting left turn traffic from a roadside facility and/or for accommodating the left-turn deterred (or diverted) traffic through the above strategies? Yes ___ No____

If yes, could you include a copy of the standards? Yes ___ No____

Are these standards applicable to: Existing Roads______ New Roads _____ Both______

What is your experience (e.g., safety on through road and on adjacent facility, delay on through road, adjacent facility, and intersection, etc.) and public acceptance with any of these strategies? (Please use a separate sheet if necessary.)

____

____

____

4. Can you share any additional experiences, observations, criteria, requirements or needs for restricting left-turns traffic from a roadside facility and accommodating left-turn deterred traffic from these facilities?

Thank you for completing the survey.

Please return the survey to:

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University of Dayton
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E-mail: Mashrur.Chowdhury@notes.udayton.edu

Survey Respondents

First	Last	Email address	Phone #	Company	Address1	Address2	City	ST	Zip
Timothy	Taylor		334-242-6272	Alabama DOT	1409 Coliseum Boulevard		Montgomery	AL	36130-3050
Muhannad	Zubi	azubi@dot.state.az.us	602-712-7601	Arizona DOT	2828 N. Central Ave.	Suite 900	Phoenix	AZ	85004
Phil	McConnell		501-569-2336	Arkansas Hwy and Trans. Dept.	P.O. Box 2261		Little Rock	AR	72203
Randall	Grunden	rgrunden@mail.dot.state.de.us	302-760-2145	Delaware DOT	P.O. Box 778		Dover	DE	19903
Brad	Steckler	bsteckler@indot.state.in.us	317-232-5137	Indiana DOT	100 N. Senate Ave.	Room N848	Indianapolis	IN	46204
Chad	Smith	Chad.smith@dot.state.ia.us	515-239-1545	Iowa DOT	800 Lincoln Way		Ames	IA	50010
Linda	Voss	voss@ksdot.org	785-296-3618	Kansas DOT	217 SE 4th		Topeka	KS	66603
Charles	Sterling	Charles.sterling@state.ma.us	617-973-7360	Mass Highway	10 Park Plaza	Suite 3510	Boston	MA	02116
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Mac	Finley	finlem@mail.modot.state.mo.us	573-751-4994	Missouri DOT	2211 St. Marys Blvd.		Jefferson City	MO	65109
Gilbert	Rogers	Grogers@dot.state.nh.us	603-271-3734	New Hampshire DOT	1 Hazen Drive	P.O. Box 483	Concord	NH	03302-0483
Charles	Guenzel	Charlie.guenzel@dot.nj.us	609-530-6579	New Jersey DOT	1035 Parkway Avenue	P.O. Box 600	Trenton	NJ	08625
Steve	Munson	smunson@gov.dot.state.ny.us	518-457-3429	New York DOT	Agency Building 4, Room 209	State Office Campus	Albany	NY	12232-0429
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